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FROM THE EDITOR

Thinking like a biologist

Charles Day

My wife, Jan, keeps bees on the second-story porch of our rowhouse in Washington, DC. When she extracts the honey from the hive's wooden frames, she keeps the beeswax and uses it to make candles.

Beeswax is a superb material for candles. It burns cleanly, efficiently, and with a subtly pleasant smell. Beeswax is also harder than other candle waxes and has a high melting temperature. Humans have long recognized those favorable properties. In the Middle Ages, it was used for dental fillings. In World War II, it was used in the US to stabilize the high explosive Torpex until a synthetic substitute was developed.

Jan's candle making requires more beeswax than her hives can supply, so she buys beeswax in bulk. When her regular supplier ran out in January, she turned to an alternative supplier, whose beeswax happened to be cheaper. Unlike the regular supplier's beeswax, which comes in a thick, golden-brown cake, the alternative supplier's came in the form of white pellets. Jan was struck by the difference. When she tested a candle made from the new beeswax, it collapsed into a milky-looking puddle.

After she told me about her experiment, I began to speculate on possible explanations. Lard is a solid, whereas vegetable oil is a liquid. The difference, I remembered, is due to the greater proportion of double carbon bonds in fatty acids that make up the solid compared with the liquid. Could that be the cause of the alternative wax's softness?

Curious, I took to the interwebs to discover what beeswax is made of. I found the answer on Bristol University's Chemistry of Bees website: "at least 284 different compounds, mainly a variety of long-chain alkanes, acids, esters, polyesters and hydroxy esters."

It was then that I realized I'd been thinking like a physicist and not like a biologist. Worker bees secrete flakes of wax from glands on their lower abdomens. The bees chew the wax to soften it before adding it to a cell. The wax's molecular constituents are derived from what bees eat: honey. To make 1 gram of wax, a worker bee consumes 8 grams of honey.

YOU CAN READ DUDLEY HERSCHBACH'S COMMENTARY ONLINE AT physicstoday.org/April2018d

To serve as a hive's building blocks, the wax cells must maintain their structural integrity in the hottest summer weather. And to maximize the storage volume for larvae and honey year after year, the wax must be tough and durable even when formed in a thin layer. The multitude of individual molecular species in beeswax is the result of millions of years of evolutionary optimization. Beeswax is how it is because of what it has to do.

My failure to look at the problem from a biological perspective brought to mind an opinion piece that Dudley Herschbach wrote for this magazine 21 years ago (see PHYSICS TODAY, April 1997, page 11). After identifying himself as both a physical chemist and a chemical physicist, Herschbach noted the disdain that some physicists have for chemistry. "A diatomic molecule has one atom too many" was among the remarks that he quoted. To demonstrate that the disdain is misplaced, he invoked three anecdotes, the last of which was, to me, the most impressive. In 1993 Harvard University chemist Yoshito Kishi succeeded in synthesizing a molecule's one stereoisomer among 2^{72} that is a potent natural neurotoxin. Kishi pulled off that feat by thinking like a chemist.

As for the mystery of the alternative beeswax, Jan's beekeeping mentor, Toni Burnham, came up with a plausible solution. In making soap, Burnham had noticed that if she didn't add beeswax at just the right point, the soap failed to solidify. Trying again with recovered ingredients didn't work because the wax had been altered chemically, physically, or both. Burnham hypothesized that the process used to turn beeswax into pellets had irrevocably altered the wax. For some applications, the alternation was immaterial. For making Jan's candles, it wasn't.

Jan found support for Burnham's hypothesis with a physical experiment. She poured equal volumes of melted wax of both types into separate containers and then weighed them. The densities of the two waxes were identical.

On page 48 of this issue you'll find another biological mystery. In their feature article "Lubrication of articular cartilage," Sabrina Jahn and Jacob Klein recount their and others' investigations into the molecular origin of cartilage's remarkably low frictional coefficient. As in the case of beeswax, the answer lies in multiple types of molecules acting together. PT